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# Charcoal Analysis

Methodological Approaches,  
Palaeoecological Results and Wood Uses

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# Charcoal kilns and environmental history in the eastern Pyrenees (France). A methodological approach

Jérôme Bonhôte, Bernard Davasse, Claude Dubois, Véronique Izard,  
Jean-Paul Métaillé

CNRS-UMR 5602, GEODE,

Maison de la recherche, Université Toulouse-le Mirail, 31058 Toulouse, France.

## Abstract

Since 15 years, an interdisciplinary research program on long-term forest history and the impact of metallurgy has been undertaken in the eastern Pyrenees. The objective is to describe the spatial evolution of forests and pastoral landscapes and the principal historical events and their causes. Our methodology is based on large-scale regressive studies of various characteristic sites (in valleys or forests) and includes the application of history, phytogeography, palynology, anthracology and archaeology. Remains of charcoal kilns are numerous in the mountain forest areas, whether these are actual or potential, all over the eastern Pyrenees and in particular in Ariège and in the Catalan mountains. Charcoal kilns can thus be used as a tool for reconstructing environmental history and ancient woodlands. Two different methods are described here: an anthraco-biogeographic method, based on a geosystemic approach, comparative studies and spatialisation of results and an archeo-environmental method, that allows a precise diachronic study of limited forest units and charcoal kiln sites.

**Key-words:** Eastern Pyrenees, Forest history, Charcoal kiln, Phytogeography, Palynology, Anthracology, Archaeology.

## Résumé

Un programme interdisciplinaire de recherche est conduit depuis 15 ans sur l'histoire des forêts et l'impact de la métallurgie dans les Pyrénées de l'est. L'objectif est de décrire l'évolution spatiale des paysages forestiers et pastoraux, les principaux seuils historiques et leurs causes. La méthodologie est basée sur l'étude régressive à grande échelle de sites caractéristiques (vallée ou unités forestières), en utilisant l'histoire la phytogéographie, la palynologie, l'anthracologie et l'archéologie. Dans toutes les Pyrénées de l'est, en particulier en Ariège et dans les montagnes catalanes, les restes d'anciennes charbonnières sont innombrables dans l'ensemble de l'aire de la forêt, actuelle ou potentielle. Les charbonnières ont donc été utilisées en tant qu'outil pour l'histoire de l'environnement et la reconstitution des forêts du passé. Deux méthodologies sont décrites : la méthode anthraco-biogéographique, qui est basée sur une démarche géosystémique et permet une approche comparative et spatialisée ; la méthode archéo-environnementale, qui permet une étude diachronique précise d'unités forestières limitées et des sites de charbonnage.

**Mots-clés :** Pyrénées de l'est, histoire des forêts, charbonnière, phytogéographie, palynologie, anthracologie, archéologie.

## Charcoal kiln records: a tool for reconstructing environmental history

Research on charcoal kiln sites and their role as a palaeoecological source for the reconstruction of the history of Pyrenean forests was initiated in the upper Ariège in 1986-87. This area is one of the main centres of metallurgy in the Pyrenees and the initial research revealed the scientific potential of this type of sites. The very numerous charcoal-burning sites are distributed in all the forests, and even in mountain pastures, where they

represent the evidence of disappeared forests (Bonhôte and Vernet, 1988). Research on forests was developed since the beginning of the 1990s in the whole eastern part of the range (fig. 1), in the framework of several Ph.D. theses and interdisciplinary programs, which have now yielded significant results on the long-term history of Pyrenean environments. The results concern at least four different fields of research:

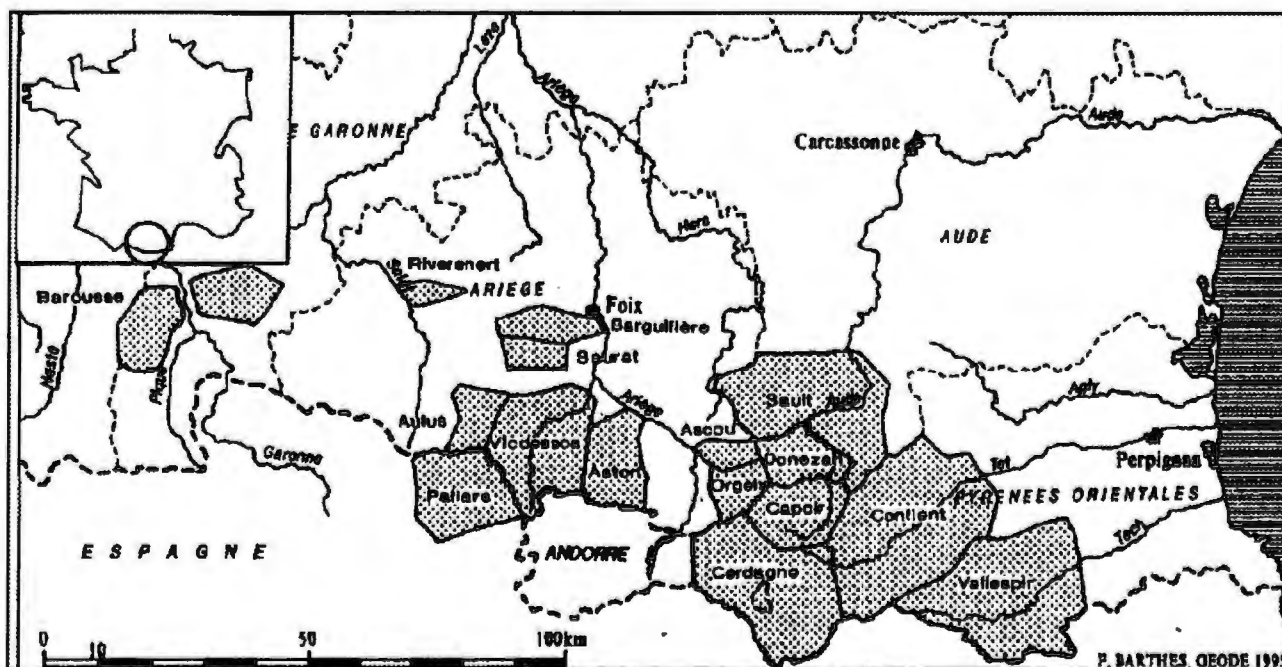


Figure 1: Localisation of study areas in the eastern Pyrenees.



### *Historical cartography of the environment*

In the valleys of the Catalan Pyrenees and in the upper Ariège region, the development of metallurgy, most often starting in the Middle Ages but sometimes as early as in the Classical period, entailed an extensive exploitation of forests for charcoal production. No forest has escaped from this, whatever its altitude or topographic situation. Charcoal burning sites thus constitute a reliable indication of the past exploitation of forests and their period of activity can be determined by radiocarbon dating. The study of numerous charcoal kilns, located in current pasture areas, allows us to map the extension of former woodlands and to establish their specific composition. The extension of past deforestation can be quantified and its impact on the upper forest limit can be determined. This limit is now situated at an average altitude of 1400-1600 m a.s.l. while its potential altitude would range between 1800 and 2400 m a.s.l. Ancient charcoal kilns are found at altitudes of 2300-2450 m a.s.l. (Bonhôte and Vernet, 1988; Bonhôte and Métaillé, 1993).

### *The chronology of the formation of landscapes and deforestations*

The data obtained from archaeology, biogeography, geomorphology, archive sources and palaeoenvironmental studies have allowed the elaboration of a chronological model for the eastern part of the Pyrenees. This model reconstructs various phases of landscape formation and highlights the major turning points in the relationship between human societies and the environment (Bonhôte *et al.* 2000). Pastoral colonisation starts during the Neolithic (*c.* 4500 BC) and the generalisation of pastoral practices takes place during the Bronze Age (*c.* 2200 BC). Metallurgy and charcoal production have an impact on the landscapes of the Catalan Pyrenees as early as in the Classical period, even though the intensification of these activities does not occur in the valleys of Ariège until the medieval period. In the beginning of the XIV<sup>th</sup> century, the introduction of hydraulic forges (mouline, iron mill) represents a major event, resulting in a first forest crisis and the promulgation of regulations. A second limit is reached in the XVII<sup>th</sup> century, due to population growth, metallurgy (invention of the Catalan forge) and agro-pastoral practices. During the XVIII<sup>th</sup> century the deforestation at higher altitudes (*i.e.* above 1700 m) comes to an end.

### *Evolution of the specific composition of the forests*

Early historical studies have already pointed to the role played by human activities in the expansion of *Fagus* and the rarefaction of *Abies* (Fruhauf, 1980; Bonhôte and Fruhauf, 1990). The time and place of similar processes could be determined in the various valleys, where the expansion of beech always marks an intensification of the human impact. However, the evidence is not unequivocal: there are, for example, cases of protected forests "bedats" from the end of the Middle Ages, in which beech was replaced by fir. In the last centuries, oak woodlands have been favoured by an intensified exploitation of the lower slopes. Anthracological research has also revealed the probable existence of vast forests of *Pinus sylvestris* in the upper

Ariège until the XVII<sup>th</sup> century. Until now, this phenomena was unknown to phytogeographers who considered the climate too humid for such forests to grow there.

### *The role of metallurgical activities for the promulgation of forest regulations*

In the Catalan mountains, the impact of metallurgical activities on the forest cover led the lords to announce protective promulgations in the XII<sup>th</sup> century, and overall regulations from the XIV<sup>th</sup> century (Izard, 1999). In Ariège, various local regulations date from the XIV<sup>th</sup> to the XVIII<sup>th</sup> century (Verna, 1994; Davasse, 2000). The exploitation of woodlands was organised well before the intervention of the central royal power, which starts during the Reformation of 1669 (and hardly touches the province of Roussillon before the XIX<sup>th</sup> century). The archaeological analysis of charcoal kilns is part of an interdisciplinary research program, based on the analysis of sites at different scales, spanning from the archeological site to the valley, forest unit or mountain slope. The preferred scale for anthracological-biogeographical studies was until now the "charcoal site" that constitutes a coherent unit of exploitation. The chosen unit corresponded, in the majority of cases, to a slope, a secondary small valley or a forest, while historical and phytogeographical studies were done at the scale of the valley. Before presenting a critical synthesis of our research methods, we will first discuss, in a more general manner, various aspects of charcoal burning in the Pyrenees.

## **Charcoal production in the Pyrenean forests: data from historical sources and fieldwork**

### *Different types of carbonisation processes and their traces*

The two types of charcoal burning structures used elsewhere in Europe (kilns or pits) are also known from the Pyrenees, although they are not always easy to distinguish from each other in the written sources. Moreover, they were probably used simultaneously, from the beginning of iron metallurgy until the XIX<sup>th</sup> century. The main difficulty in studying these processes is the lack of descriptions of ancient practices, as the charcoal production did not start to interest engineers until the end of XVIII<sup>th</sup> century.

### *Charcoal pits (charbonnières en fosse)*

The production of charcoal in pits seems to have been most widespread during the times of the low furnace metallurgy and was described by Biringuccio in his book "Della pyrotechnica" (1540). This method, known from many European countries until the XIX<sup>th</sup> century and from Africa (Bielenin, 1993) consisted of the filling of a cylindrical hole with wood. In the Pyrenees, we found mentions of "pits". In Catalonia, in the XIV<sup>th</sup> century, they were named "sitges cubertes". In order to avoid forest fires, a royal decree from 1345 prohibited the use of charcoal kilns. The pit process is used in Catalonia until the XVII<sup>th</sup> century (Izard, 1999). In Pays de Sault (Aude), charcoal sites named fosses (pits) are mentioned in 1730. These generally consist of small structures, corresponding to 1/4-1/2 pile (1-2 m<sup>3</sup> of wood). Some

of them are somewhat larger, attaining 3–4 m<sup>3</sup>, but still remain relatively small (Bonhôte and Fruhauf, 1990). We know nothing about their form or depth. In Ariège, pits are mentioned until the XIX<sup>th</sup> century. For example in An 13, a 6–7 m long pit is described from the forest of Gourbit (Bonhôte, 1998). The description suggests that the pits were not very deep but elongated, probably in order to facilitate ventilation.

The charcoal production in pits is still not very well known, especially as no site has yet been found and excavated in the Pyrenees. An explanation to this may be their small size, mentioned in the texts, which would have left less traces in a mountainous context where colluvial processes quickly obliterate superficial features. Some sites presenting considerable deposits of charcoal (up to 80 cm) and which have been cored might correspond to small pits, but they have not yet been excavated.

### *Charcoal kilns (charbonnières en meule)*

Since Theophrastus (III<sup>rd</sup> century BC), there are numerous mentions of charcoal kilns (meule) in the texts. There are also numerous remains of this type of structures along the mountain slopes. Nevertheless, we still do not know very much about the practices and their evolution through time. Indeed, descriptions of charcoal kilns and their functioning from the XIX<sup>th</sup> century are not directly transposable to medieval or more ancient practices. For example, the use of the term *meule* was introduced by engineers from les Mines in the XIX<sup>th</sup> century. Before that, a charcoal kiln was called “furnace” (fourneau) or “faulde” in Ariège and “farregans” in Catalonia.

In the XVIII<sup>th</sup> century, De Gensanne (1775) described charcoal kilns of 15–20 steres (*i.e.* 4–5 piles). This corresponds to kilns with an average diameter of 4–5 m and with platforms measuring 5–7 m. The most recent and best preserved sites noted during fieldwork belong to this size class. François (1843) also quotes kilns of 10–20 steres in the mountains and 20–40 steres in the plain. The kilns built illicitly by charcoal burners or inhabitants of the countryside, and described in the texts, were generally much smaller and sometimes produced 2–5 bags of charcoal from no more than 1–2 m<sup>3</sup> of wood. The resulting remains are in these cases scarce and therefore more difficult to find and interpret.

During surveys and excavations, an inventory of all sites was made, independently of their size, altitudinal position and topographical context. Both bigger (6x7 m or more, multiple sites with a surface of several hundred m<sup>2</sup> can be found) and smaller (2x4 m or less) sites were included in this inventory. The results are in accordance with descriptions of charcoal kilns in written sources. The presumably oldest sites (badly preserved, colluvial depositions) seem smaller, but this could be an effect of the colluvial deposition. In fact, after excavation, medieval sites that were badly preserved seemed to be of “normal” size, *i.e.* in average 5x5 m.

### *Logging and transport of wood; localisation of charcoal kilns in mountain slopes*

We do not know much about the practices of forest exploi-

tation by charcoal burners in the Pyrenees, except for the XVIII<sup>th</sup> and XIX<sup>th</sup> centuries, when controlled exploitations in state forests or seigniorial domains appeared. In the Pays de Sault, for example, beech wood was preferentially chosen for the production of charcoal in order to make place for fir trees. In the Aston valley, the exploitation of forests was done without precise rules (irregular coppices or clearing of high stands) until the XVIII<sup>th</sup> century. From the XIX<sup>th</sup> century on, coppices were managed in a regular manner (Bonhôte, 1998). Summary descriptions exist in the official reports on forest offences, in particular from the XVIII<sup>th</sup> and XIX<sup>th</sup> centuries. In the sediments of the kilns, we often found big charcoal pieces that indicate the use of whole trunks, especially when the charcoal kiln was large. Photographic documents or investigations concerning recent practices also confirm this. It is likely that roots and branches of fir were charred even in areas where the exploitation of fir was prohibited. The archives confirm this practice and, for example in the crown forest of Lercoul, charcoal from fir is found in kilns that date to the XVIII<sup>th</sup> century, *i.e.* to a period when this species was particularly protected (Dubois *et al.* 1996). In XIV<sup>th</sup> century Catalonia, regulations protect the fir tree, but nevertheless authorise the use of its branches. The same regulations protect pioneer species such as *Betula* and *Fraxinus* (Izard, 1999). For the Middle Ages, forestry practices can sometimes be known through palaeoenvironmental research. For example, in the Aston valley, palynological and anthracological analyses have revealed long-term exploitation cycles, certainly involving forest clearing (Davasse, 2000; Galop, 1998).

Topographic constraints seem to have limited the transport of wood in the Pyrenees. Practices of launching wood down steep slopes or transporting it over short distances, when a site was not favourable for the construction of charcoal burning kilns, are known. The transporting techniques were probably not very different from those still used in the XX<sup>th</sup> century in various mountainous areas where a simple, forked branch allowed the carrying of a faggot on the shoulder. Long-distance transport would have been possible when a charcoal kiln was constructed illicitly and required lesser quantities of wood. Some doubts about the precise origin of the wood could arise concerning charcoal kilns situated near mountain ridges, as the raw material could have come from either side of the ridge. Wood could also have been stolen in neighbouring forests.

The distribution of the charcoal kilns is a function of the topography. If it was soft and regular and if the substrate was easy to work, the charcoal burners built many kilns in the same area in order to transport the wood as little as possible. For example, in the valley of Barguilière, there are up to 15 charcoal kilns per ha (Davasse, 2000). In the Picaussel forest (Pays de Sault), a land surveyor noted in 1737 the presence of 95 charcoal kilns on 14 acres, *i.e.* an average of 13 kilns per ha (Bonhôte and Fruhauf, 1990). If the topography was abrupt, sites were concentrated at the base of slopes where wood was launched through natural “corridors”. In the field, we noted that slopes exploited in this way could rise to a height of 200 m, with a potential area in the shape of a triangle. Even though the re-use of charcoal burning localities is frequent over the centuries, the kilns in the Pyrenees are not established with the same intentions of

durability as those of the Languedoc garrigues during modern times (Fabre, 1996).

### *Preparation and construction of the kiln*

The lack of precise data on techniques used in the Pyrenees, leaves us with much incertitude about the way charcoal kilns were built at various periods. We therefore have to investigate the remains of ancient kilns and the few historical sources that are available.

Construction of a charcoal kiln in a steep mountain slope required careful preparation of the site. The site consisted of platforms and embankments resulting from earthwork. The slope was often consolidated with stones or even by actual stone walls, attaining 1,20 m in particularly steep slopes. Regular stone bases are often noted but their precise function remains unknown: were they used for ventilation of the wet ground or for insulation? Theoretically, charcoal kilns are not built on wet ground as humidity can provoke a bad combustion or even explosions. In spite of this, charcoal kilns on peat bogs are not rare. The exact construction techniques for kilns are badly known. In France, kilns mostly comprise a central chimney for firing and aeration. Kilns without chimney still exist in Liguria while, in Portugal, the lighting of the fire is done through a tunnel at the base of the kiln. In the XX<sup>th</sup> century Aragon, the production of small-size charcoal for braziers "picòn" was still made by putting fire to a heap of faggots, that was covered with earth once it had started to burn. It is thus unlikely that only one technique of charcoal production was employed from the Classical period until the XIX<sup>th</sup> century.

After the construction of the kiln, the wood was normally covered by a layer of plant material (leaves, grass, moss, branches...) and a layer of fine soil. In the Pyrenees, charcoal from *Sarothamnus*, *Rhododendron* and *Calluna* seems to come from this insulating layer. Another technique consisted of the posing of pieces of turf directly on the wood, the grassy side towards the interior. Contemporary charcoal burners prefer to re-use the soil that covered ancient charcoal kilns "fraisil" and a transfer of soil from one site to another is thus possible. Such a practice, leading to the mixing of charcoal pieces of different ages and origins, can of course trouble the anthracological and chronological interpretation of a deposit. However, this was probably done only when two sites were close to each other and more or less contemporaneous, which would then diminish the risk of error. The heavy colluvial deposition, which generally occurs in mountain slopes, prevents the recovery of charcoal from sites that were abandoned since a long time. Excavations also show that ancient sites were re-used without the removal of colluvial layers and the earlier charcoal deposits thus most often remain intact. Even if the degree of mixing of the layers is difficult to evaluate, it probably remains limited.

The distribution of charcoal on a burning site depends on the methods used for the construction and dismantling of the kiln. In the centre, we will find charcoal from the chimney (when this type of burning was used). Sometimes, this charcoal consists of dry branches that can come from far away. *Juniperus* wood has for example been found here. At

the periphery of the kiln, the remains result from the spreading and cleaning out of charcoal, but they can also correspond to shrubs and branches used to cover of the kiln (*Genista*, *Rhododendron*, *Calluna*, *Buxus*). It is thus preferable to study charcoal from a transect crossing the whole site in order to obtain a complete image of the species used.

### *The representativeness of charcoal*

Even though we do not really know how the charcoal kilns were constructed or operated, we observe an important and rapid accumulation of charcoal debris on Pyrenean sites. In general, the deposits are 20 cm thick and cover the entire surface of the site. Often, these deposits can also consist of successive layers, 40-50 cm thick. Layers of 80 cm have also been noted. This accumulation of refuse is not common everywhere. For example in Liguria, the meticulous cleaning of the site after each burning event does not leave the charcoal *in situ*. Instead, it is found at the foot of the site in refuse dumps resulting from the cleaning out of the kiln. In the Pyrenees it is on the contrary possible to undertake a stratigraphic analysis of the deposits, extremely rich in charcoal fragments.

In order to better control the combustion, charcoal burners normally used only one species for the construction of a kiln. Anthracological analysis shows that the choice of this species depended rather on availability than on combustion properties. Thus, any species available in the surroundings was exploited, especially during the last centuries when wood resources had become more rare: pine (*P. uncinata*, *P. sylvestris*), *Abies alba*, *Fagus sylvatica*, oak (*Q. petraea*, *Q. pubescens*, *Q. ilex*), *Corylus*, *Tilia*, *Prunus*, *Crataegus*, *Alnus*, *Castanea*, *Ilex*, *Acer*, *Fraxinus*, *Sorbus*, *Juniperus*, *Betula* and *Salix*. This "eclectism" is attested since the Classical period by the study of charcoal from slag deposits from low furnaces dating to the 1<sup>st</sup> century (Izard, 1989).

We consider that the Pyrenean charcoal kilns reflect the surrounding forest environment. However, the problem of wood transportation is likely, in certain cases, to disturb the representativeness and interpretation of the samples and should not be underestimated (see the example of Tignalbu. charcoal kiln 1, fig. 3).

### *Consequences of the charcoal representativeness on the field surveys*

The active slope dynamics of the Pyrenees, resulting in important colluvial deposits in the Mediterranean area, constitute a problem for surveys. Remains of charcoal kilns, buried under colluvial deposits of 50-1,50 m and sometimes stones, can frequently be seen along roads and tracks in the Catalan valleys and in particular in the lower and steep mountains of Vallespir, Aspres and Conflent. The discovery of such charcoal kilns during a survey is practically impossible and one may presume that most charcoal sites older than the XVII<sup>th</sup> century belong to this category or have simply been eroded (Izard, 1999). In Ariege, on the Atlantic side, the erosion is less important and the platforms are generally visible, even those from the Middle Ages. However, colluvial deposits exist, even in forests, and require the coring or systematic excavation of layers loca-



ted uphill from the visible site: frequently, the oldest charcoal layers are covered by colluviums and the more recent site has been shifted downhill (Dubois *et al.* 1998). In areas used for pasture, the trampling of herds often results in charcoal layers without any apparent topography. In the upper mountain grasslands with *Festuca eskia*, the accumulation of organic matter can be significant and hide charcoal layers under a 20-40 cm thick layer of roots.

The survey of the sites includes direct observations of the topography, a reconstruction of different factors involved in the establishment of the kiln (possibilities of launching, proximity to water etc.) and a systematic or random research on the soil, carried out with the help of an earth auger or a shovel. Generally, the soils of charcoal kilns are black except when the structure is old or little used. However, the presence of charcoal, even small-sized, reveals the existence of a charcoal burning site. It is true that most soils in the Pyrenean mountain slopes contain charcoal fragments when observed from a micro-morphological point of view. However, the presence of charcoal pieces measuring a few millimetres and observable in the soils with the naked eye always reveals the presence of a charcoal kiln situated uphill. There can be some doubts, however, when few and small-sized charcoal fragments are noted at unlevelled sites and in soils that otherwise are not very dark. This configuration may rather correspond to forest fires or slash-and-burn agricultural practices. Repeated pastoral fires can also be responsible for the presence of charcoal in the soils, but characteristic taxa such as *Genista* and *Ericaceae* should then be present in the anthracological assemblages.

### Analysis of charcoal kiln sites: interest and limits of the methods used in the Pyrenean context

The methodology used during our work in the Pyrenees is based on a precise spatial unit - the charcoal burning site. Our research aims at understanding environmental dynamics at the scale of a geographical unit, defined through preliminary studies in topography, biogeography (current observations), history (archives, forest maps etc.) and archaeology (survey of surface remains whether pastoral or metallurgical) as well as through a reconstruction of forest exploitation practices.

The spatial unit defined in a mountainous zone corresponds to a slope or part of a slope, pastoral or covered by forest, with an average size of 10-50 ha and presenting an altitude gradient of 200-300 m. A site can also be delimited according to administrative boundaries of a forest or a forest parcel.

Once this delimitation has been made, a complete inventory of charcoal burning kilns is carried out within the perimeter of the site, by boring with an earth auger or by using a shovel. A certain number of charcoal kilns are selected, described from a stratigraphic point of view and then sampled for charcoal.

At this point, we can choose to apply one of two investigation methods, according to the objectives and the scale of the research: an "anthraco-biogeographic" method or an "archaeo-environmental" method.

### The "anthraco-biogeographic" method

The aim of this method is to conduct a spatial study at the scale of the valley or more. Comparisons are made between different slopes, altitudes or sites (Davassee, 2000). Preferentially, the research should be carried out by one person only and given the amount of work involved both in the field and in the laboratory, too many surveys cannot be included.

Therefore, a limited number of charcoal kilns are selected (5 kilns on average, but this number can vary according to study areas) and studied in detail. The sounding, a square with 50 cm sides, is located in the tallest part of the kiln, previously identified by the help of an auger. The sediment is then excavated by 5 cm layers until the base of the kiln. It has to be noted that intermediate soils are numerous and sometimes thick. It is also necessary to verify that no charcoal layers are present deeper down.

The sediment from each 5 cm layer is sieved through a mesh of 2 mm, a procedure that provides sufficiently large samples (about 500 charcoal pieces) for the anthracological study. Various analyses show that the optimal sample size in order to study the vegetation history of the Pyrenees is 60-120 fragments. In the eastern Pyrenees, we studied around 25 charcoal sites of this type during the last decade.

The study of Tignalbu, in the high valley of Vicdessos, is a representative example of the "anthraco-biogeographic" approach (fig. 2). It is located at 1400-1600 m a.s.l., in an area of summer pastures, like two other charcoal sites stu-

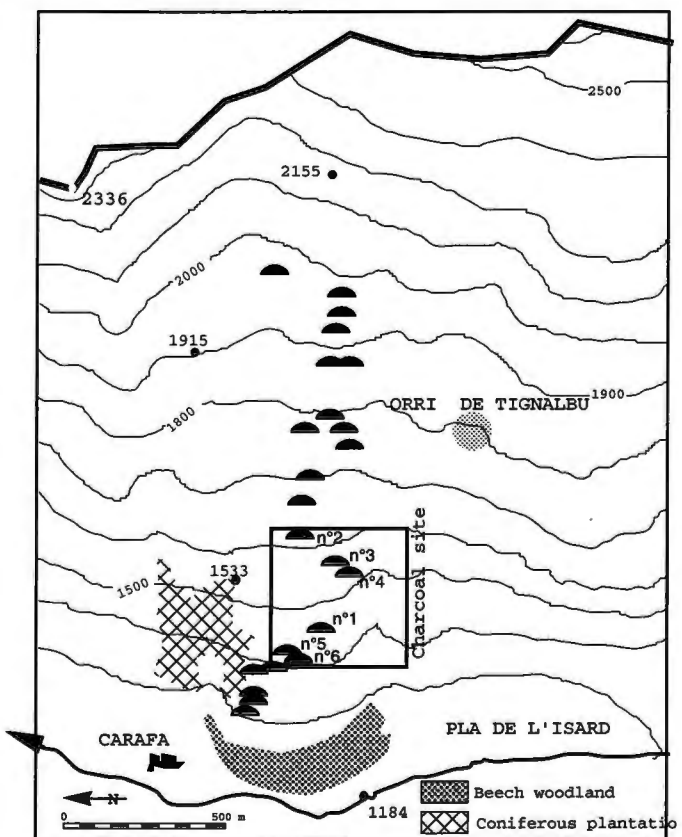


Figure 2: Site of Tignalbu (Ariège, Vicdessos) and localisation of charcoal kilns.

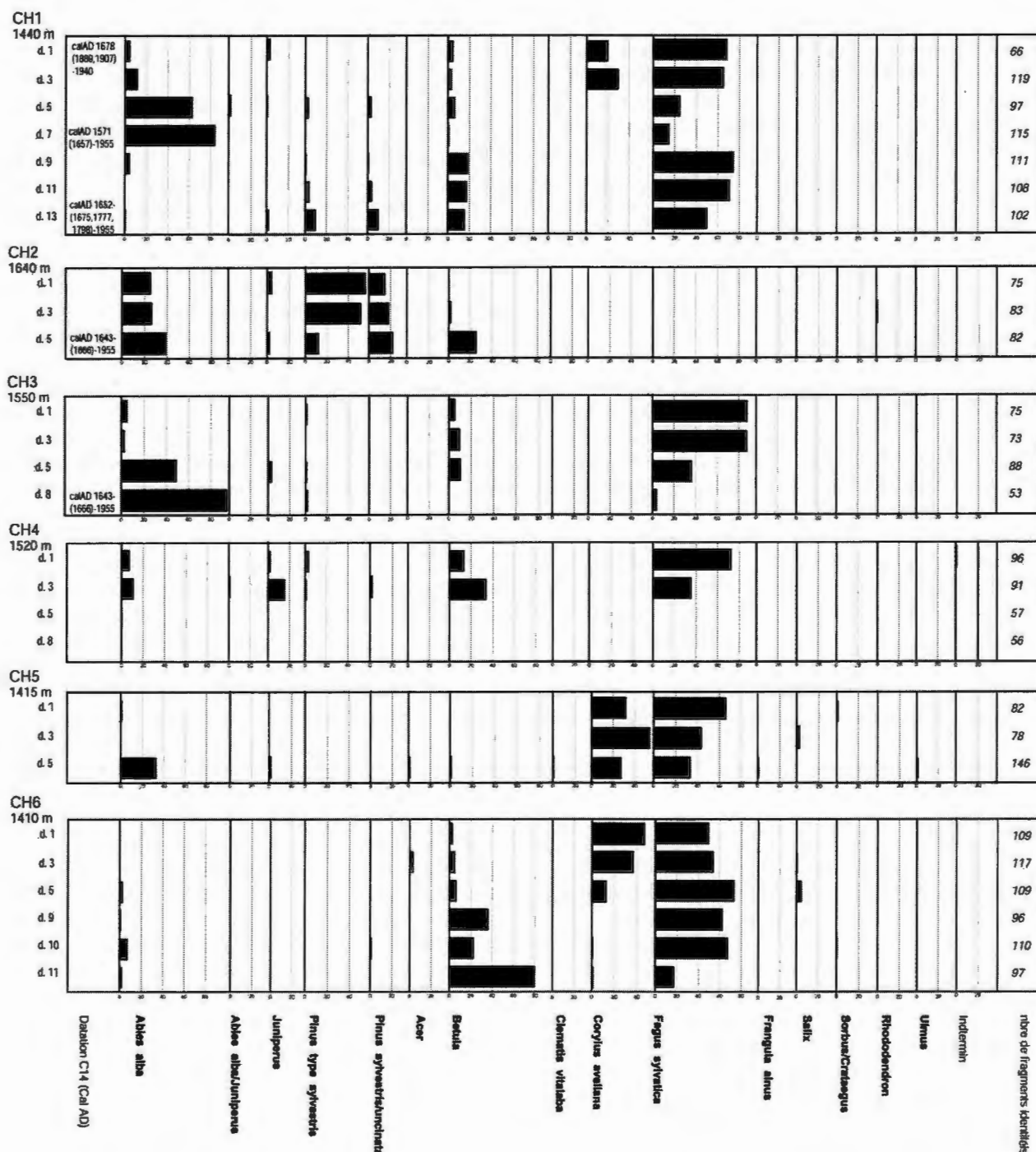


Figure 3: Anthraco-analysis of charcoal kilns at Tignalbu

died in this high glacier valley (Davas 2000, p. 173 and following). The upper timber line, situated at c. 1200-1400 m a.s.l., is particularly low at this locality. The radical deforestation is not only due to the persistence of important pastoral activities since 1800 BC (Galop and Jalut, 1994), but also to charcoal production (Davas 1992, 1993a). In Tignalbu, the charcoal from six kilns was studied, allowing the identification of sixteen taxa. A general evolution of the vegetation cover can be noted (fig. 3): beech is favoured by the forest exploitation to the detriment of fir. This evolution is observed in most charcoal assemblages in the sector, with the example of charcoal kiln 3 being particularly speaking. At the beginning of charcoal exploitation, fir was represented by 94,3% and beech by 3,8% of the identified charcoal fragments from this kiln. In the end of the sequence, the relative frequencies of these species were instead 5,3% and

88% respectively! The considerable proportions of pine should also be noted: in layer 1 of charcoal kiln 2, located at c. 1600 m a.s.l., 51,8% of the fragments belong to *Pinus* type *sylvestris*; in layer 13 of charcoal kiln 1, located at 1440 m a.s.l., this taxon is represented by 21,7%. Do we deal here with *Pinus sylvestris* or *Pinus uncinata*? Even though the distinction between these two pine species, both currently present in the Pyrenees, is difficult from an anatomical point of view it is likely, due to the high altitude of the kiln, that the exploited conifer was rather *Pinus sylvestris* (Davas, 1992).

Comparing the frequencies of *Betula* and *Corylus* highlights another type of dynamics: birch is generally present in the beginning of the sequences while hazel dominates towards the end. This is particularly obvious in charcoal



kiln 6 where the frequencies of birch and hazel pass from 79,4% and 2,8% respectively to 1% and 46,8%. The ecological requirements of these two species are, however, similar: they constitute secondary woodlands or are part of recolonizing taxa. Birch (*Betula pendula*) is a heliophilous species and a pioneer of moorlands and cleared forests. Consequently, it disappears when the forest cover becomes denser. It was the principal element of the forest recolonization of deforested slopes in the valley of Vicdessos throughout the XX<sup>th</sup> century. Hazel occupies abandoned lands where it constitutes relatively stable thickets. This species is also introduced into degraded beech coppices. At present-day, hazel is abundant below 1400-1500 m while birch thrives at higher altitudes. It is difficult to explain their dynamics. Perhaps it is necessary to take into account that one species is more heliophilous than the other? In that case, different exploitation patterns could be the explanation, as clear cutting would favour the growth of birch and coppicing that of hazel. In any case, the presence of these two species in the beginning of the sequence indicates that the surrounding woodlands were already exploited at this point.

When looking into details, the interpretation becomes complicated. The case of charcoal kiln 1 (fig. 3) is revealing. Three different phases could be distinguished in the charcoal layer. The first phase is characterised by the preponderance of beech (50-74,8 % of the fragments) and the presence of birch and pine. In the second phase, fir dominates with up to 84,3% of the fragments. During the third phase, beech and hazel are present. These phases had initially been interpreted as exploitation cycles because of the presence of sterile layers in the profile (Davasse, 1993a). However, radiocarbon dates seem to indicate only two periods of exploitation, the first occurring during the XVII<sup>th</sup> century and the second more or less a century later. Colluvial deposits separate these two periods, represented by layers 4 and 5.

The contemporaneity of beech and fir in the charcoal assemblages can only be explained by the exploitation of separate forest parcels, which would suggest a management of woodlands. However, as seen above, the protection of fir stands for building purposes was the principal form of forest management conducted by local communities. The results obtained thus allow two different interpretations: either high fir trees were cut down for construction wood and their branches used for charcoal, or whole stands of fir were exploited indifferently for charcoal burning. This happened at a time when offences to the forest regulations became more and more frequent, due to an increased demand for wood resources.

The method described here allows us to study vast spaces and to make comparisons between several sites. It also includes a spatial dimension, taking into account the results on the scale of a slope, a great forest, a large valley etc., all while following the principles of geosystemic classification. By adding the radiocarbon dates obtained at various sites, this procedure allows us to validate or invalidate historical and biogeographic hypotheses.

The small size of a charcoal kiln excavation constitutes the main limiting factor to the understanding of the forest history in a given place. All structures cannot be revealed and

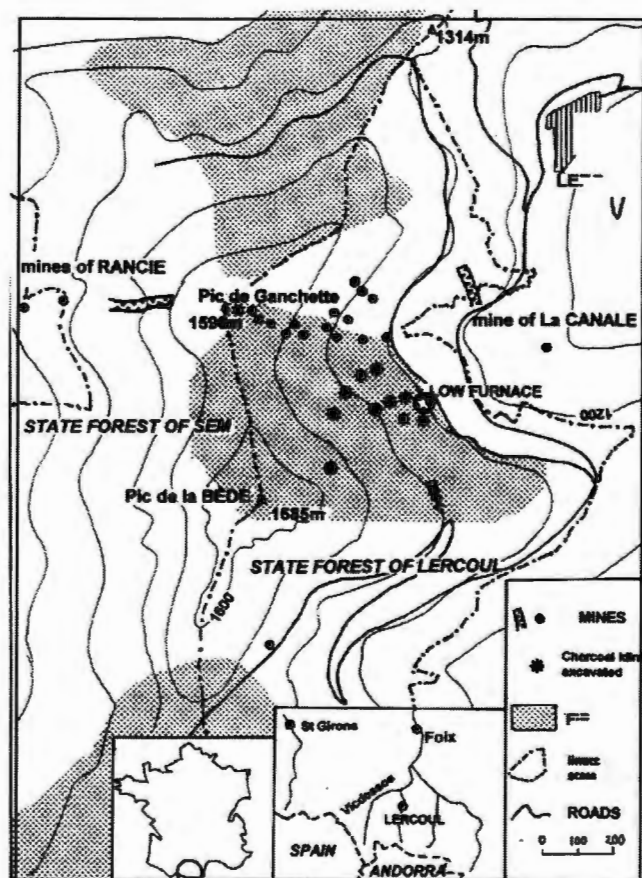


Figure 4: Localisation of the forest of Lercoul.

stratigraphies are difficult to correlate from one kiln to another. Inevitably, the sampling does not take into account topographic shifts occurring through time. The charcoal site can be analysed, not without difficulty, as a diachronic feature, reflecting successive practices.

### The "archeo-environmental" method

The aim of this method is to carry out a complete analysis of the vegetation history and wood use at a single charcoal site, considered as "global" at the scale of a geo-complex. After a first survey, similar to that described above, a limited number of charcoal kilns are selected. These are excavated by the removal of successive strata, aiming at determining the various charcoal layers, their extension, intermediate soils and colluvial deposits in order to understand the diachronic evolution of the site. It should be recalled that charcoal kilns in mountain areas are frequently covered by colluvial deposits that destroy the upper part of the kiln. The excavation of such a site can therefore be particularly constraining due to the considerable volume of sediments to be evacuated. However, it is seldom useful to excavate the whole charcoal kiln site, especially if the aim of the study is to reconstruct the exploited vegetation through charcoal analysis. Instead, a system with two perpendicular trenches, as broad as a shovel and meeting at the supposed summit of the kiln, can be used. The limits of the charcoal layers are much clearer when seen in a stratigraphic section than at the surface. The two trenches, forming a cross, allow the observation of each stratigraphic layer and the estimation of its relative significance. From these observations, an excavation strategy can be established where 1/4, 1/2 or 3/4 of the site will be excavated. 1/4, at least, of the site will always be kept untouched.

Moreover, the distinct stratigraphic sections are easy to sample. Sediment samples are taken from arbitrary 5 cm layers, as in the "anthraco-biogeographic" method, and sieved through a 2 mm mesh.

This method was applied to the site of the Royal Forest of Lercoul (Ariege) (fig. 4) (Dubois *et al.* 1996; Dubois and Métaillé, to be published). Today, this forest consists of high fir stands, attested by the archives since the XVII<sup>th</sup> century. Research was initiated at this site after the discovery of a low-furnace from the Classical period (III<sup>rd</sup> century). The slag heap of this furnace contained only beech charcoal and a quick anthracological survey of 25 charcoal kilns in the area confirmed the predominance of beech in the past. These first results brought us to excavate, in an exhaustive manner, 10 charcoal kilns situated within a perimeter of 7 ha. 17 radiocarbon dates were obtained, spanning between the V<sup>th</sup>/VI<sup>th</sup> centuries, for the oldest charcoal kiln, and the XVII/XVIII<sup>th</sup> centuries, for the most recent one. This represents the longest available sequence for forest history in the Pyrenees and probably for French mountains in general. The anthracological results made it possible to describe the evolution of a woodland that was already extensively exploited in Antiquity. While this woodland was mainly characterised by the presence of beech in the earliest periods, fir stands took over from the end of the Middle Ages (XV<sup>th</sup>-XVI<sup>th</sup> centuries), when protective measures were taken by the communities and the Earl of Foix (Verna, 1994) at the time of expansion of hydraulic metallurgy.

Charcoal kiln 30 summarizes the forest history of Lercoul (fig. 5). It is located at 1540 m a.s.l., in a stand of high fir trees. A few beech trees are growing on the rocky slope above. Even if these rocks collapsed several times on the charcoal burning site, it was re-used several times by char-

coal burners. The oldest charcoal layers (9, 34) date to the V<sup>th</sup> century and contain 85%-98% of *Fagus*, as did the III<sup>rd</sup> century slag heap (*Fagus*, 90-97%). In layer 8, dated to the XI-XIII<sup>th</sup> centuries, *Fagus* is represented by 45% of the identified fragments and *Abies* by 43%. In other medieval layers at this complex site, the average frequency *Fagus* attains 70%. The presence of other taxa, such as *Corylus*, *Betula* and *Juniperus*, indicates a cleared forest. The most recent layer (1), from the XVII-XVIII<sup>th</sup> centuries, contains mainly *Abies* (53%). The history of this charcoal kiln, as reconstructed from charcoal analysis, is in perfect accordance with the data obtained at other sites in the same forest.

This method allows a diachronic reconstruction of charcoal production and woodland evolution in a homogeneous context.

The disadvantage is the considerable excavation work involved as each charcoal kiln may require several days of digging, especially if the stratigraphy is complex (for example in the case of charcoal kiln 30). This method requires team work and does not allow an in-depth study of a great number of charcoal kilns at several sites. It should thus be applied to particularly interesting sites that have been adequately inventoried at an archaeological as well as at a historical level. These sites should also be of limited size.

## Conclusion

In conclusion, we suggest the following methodological procedures, adapted to the objectives and the geographical context of the research:

- A fast and systematic survey of charcoal burning sites in a

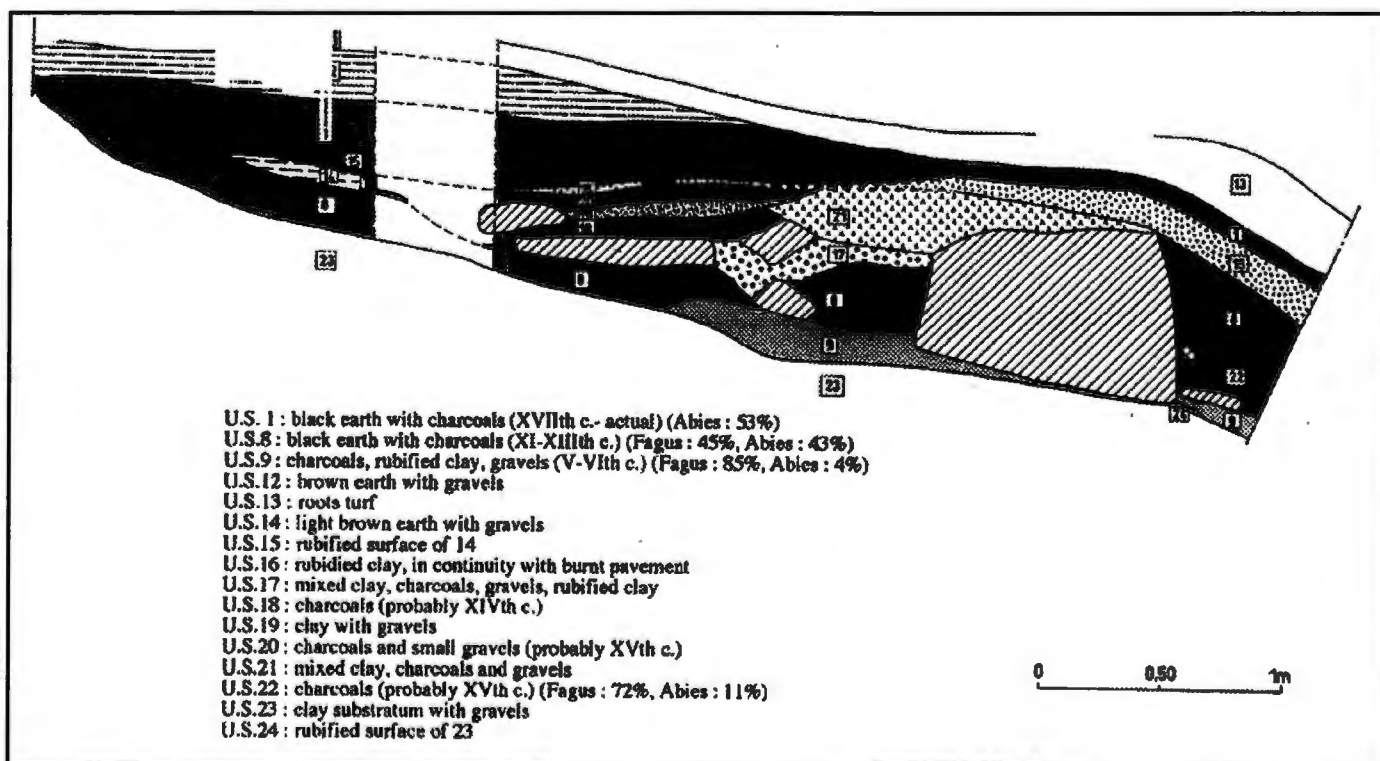


Figure 5: Charcoal kiln 30 at Lercoul, North-South section.

still provide an overall image of the sites. This survey will either precede a more thorough analysis of a chosen site or provide a general inventory of a sector. Practically, the survey is made with the help of an auger. Five points, forming a cross, are sampled by coring at all of the charcoal burning sites. Anthracological analysis is limited to the study of 10 charcoal pieces from the lower and superior levels of the stratigraphy. In this way, the stratigraphy of a site can be established rather quickly and we can get a first idea of the specific composition of charcoal assemblages as well as of the vegetation history. The use of a GPS allows a rapid localisation of the charcoal kilns on a map.

- "Anthraco-biogeographic" sites: After the first phase, described above, a selection of charcoal kilns considered as representative is made. Samples are taken from a square sounding (50x50 cm) in the centre of the charcoal kiln, *i.e.* where the thickest and most complex layers are located. The approach is based upon a geosystemic analysis of the area and allows us to inscribe the data in a precise spatial context.

- "Archeo-environmental sites": Charcoal kiln sites, selected according to their particular interest, revealed by archaeology, historical sources or surveys (implying sampling and radiocarbon dating), are excavated in stratigraphic cross-sections by the removal of successive 5 cm layers. The anthracological analysis is based on samples of 50-120 charcoal fragments per layer. This approach focuses on the reconstruction of the diachronic evolution of woodlands.

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